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Assessment of *Salmonella* prevalence in retail ground beef in Kansas.

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Abstract

Salmonella spp. is the second leading cause of foodborne illnesses in the United States of America, particularly in meat products such as ground beef, which has a high national demand. This study evaluated the *Salmonella* prevalence in retail ground beef in Kansas. A total of 278 samples were obtained from 53 stores across eight cities (C1 to C8) over a four-month period, from February to May 2024. The samples were processed using the BAX® Q7 system, a real-time PCR-based method for detecting *Salmonella*. The results revealed an overall prevalence rate of 4%, exceeding the national average of 0.85% reported by the USDA for fiscal year 2024. Cities C2, C5, and C6 exhibited the highest prevalence rates, reaching levels of 8.1%. Additionally, five of the fifty-three stores (9.43%) reported contamination rates exceeding 6%. Although no statistically significant difference was observed between fat content and the prevalence of *Salmonella* ($P > 0.05$), the results did not indicate any dependency relating these factors to the prevalence. These findings underscore the need for improved food safety controls and ongoing surveillance at points of sale. The results represent the first steps toward developing interventions to reduce *Salmonella* contamination in ground beef in Kansas.

Keywords: BAX® Q7, fat content, food safety, pathogen risk, Real-time PCR.

Resumen

Salmonella spp. es la segunda causa de enfermedades transmitidas por alimentos en los Estados Unidos de América, especialmente en productos cárnicos como la carne molida, que tiene una alta demanda a nivel nacional. Este estudio evaluó la prevalencia de *Salmonella* en carne molida de res al por menor en Kansas. Se obtuvieron un total de 278 muestras de 53 tiendas en ocho ciudades (C1 a C8) durante cuatro meses, de febrero a mayo de 2024. Las muestras fueron procesadas utilizando el sistema BAX® Q7, un método basado en PCR en tiempo real para la detección de *Salmonella.* Los resultados revelaron una tasa de prevalencia general del 4%, superando el promedio nacional del 0.85% reportado por el USDA para el año fiscal 2024. Las ciudades C2, C5 y C6 presentaron las tasas de prevalencia más altas, con niveles que alcanzaron el 8.1%. Además, cinco de las cincuenta y tres tiendas (9.43%) reportaron tasas de contaminación superiores al 6%. Aunque no se observó una diferencia estadísticamente significativa entre el contenido de grasa y la prevalencia de *Salmonella* ($P > 0.05$), los resultados no evidenciaron una dependencia que relacionara estos factores con la prevalencia. Estos hallazgos destacan la necesidad de mejorar los controles de seguridad alimentaria y la vigilancia continua en los puntos de venta. Los resultados constituyen los primeros pasos hacia el desarrollo de intervenciones para reducir la contaminación por *Salmonella* en la carne molida en Kansas.

Palabras claves: BAX® Q7, contenido de grasa, PCR en tiempo real, riesgo de patógenos seguridad alimentaria.

Introduction

Ground beef is a staple food product in the United States of America, playing a crucial role in the country's food industry. According to Our World in Data (2023), per capita beef consumption in the United States (U.S.) was 37.81 kg in 2021, reflecting an increase of 1.24 kg from 2017, with over half (57%) consumed in the form of ground products (Drouillard, 2018; Our World in Data, 2023; Rabobank, 2014). Ground beef is a preferred choice among U.S. households primarily due to its versatility and affordability. According to data from the Power of Meat 2024 Report, based on a consumer survey conducted by FMI and the Meat Institute, 80% of Americans describe themselves as meat eaters. Furthermore, 87% of meals prepared at home include meat, with ground beef being one of the most popular choices due to its versatility and affordability (The Food Industry Association [FMI], 2024; Meat Institute, 2024).

This high consumption of ground beef also brings significant food safety concerns, as foods such as beef, poultry, and eggs are common sources of infection of *Salmonella* species, which can be transmitted to humans, causing salmonellosis. This disease poses a considerable public health risk. Salmonella is a significant public health risk, causing approximately 1.35 million illnesses and 421 deaths annually in the United States (United States Department of Agriculture [USDA], 2022). Its transmission through contaminated food accounts for 96% of outbreaks, particularly affecting vulnerable groups such as children and the elderly. Furthermore, antibiotic resistance in some strains complicates treatment (Greening et al., 2022).

Among the primary bacterial causes of foodborne illnesses, *Salmonella sp.*, *Campylobacter sp.*, and *Escherichia coli* O157:H7 are commonly found in the intestines of farm animals, where they can establish themselves and multiply. This colonization poses a risk of contaminating beef and poultry during slaughter and subsequent processing (Roels et al., 1997).

Salmonella, a gram-negative bacterium, is the causative agent of salmonellosis, an illness characterized by acute diarrhea, abdominal cramps, and fever. Non-typhoidal serotypes of this bacterium are particularly associated with foodborne outbreaks, often linked to contaminated meat products (Plumb et al., 2023). The consumption of raw or undercooked ground beef is one of the primary routes of exposure, poses a significant risk to consumer health.

Between 1998 and 2008, beef was identified as the third most common source of bacterial foodborne illnesses and the fourth most frequent cause of Salmonella outbreaks. (Gould et al., 2013). This scenario highlights a concern between the increase in the consumption of meat products and the persistence of high *Salmonella* contamination rates, posing a significant risk to consumer health. Supporting this, a study by the Centers for Disease Control and Prevention (CDC) between 2009 and 2015 recorded 5,760 foodborne disease outbreaks in the United States. Of these, 2,953 outbreaks had a confirmed etiology, With *Salmonella* being the second most prevalent pathogen, it accounted for 896 outbreaks (30%) and 23,662 illnesses (35%) (Dewey-Mattia et al., 2018).

Non-typhoidal *Salmonella* is estimated to be the most common cause of bacterial foodborne illnesses in the United States, with over 1.2 million cases annually, approximately 130 outbreaks, and resulting in more than 23,000 hospitalizations and 450 deaths each year (Laufer et al., 2015; Xie et al., 2016).

The increasing prevalence of large-scale outbreaks has underscored the role of ground beef in salmonellosis, contributing to numerous outbreaks and illnesses. According to Laufer et al. (2015), a shift has been observed in the types of beef implicated in salmonellosis outbreaks, moving from roast beef to ground beef. This change is attributed to cooking and processing regulations that effectively eliminated the outbreaks associated with roast beef in 1987. Consequently, ground beef emerged as a significant vehicle for Salmonella transmission in the 2000s, being implicated in 17 of the 38 beef-related outbreaks reported between 2002 and 2011, accounting for 45% of the cases.

Additionally, a study analyzing *Salmonella* outbreaks related to beef from 2012 to 2019 identified 27 outbreaks, of which 12 (44%) were associated with ground beef, while 6 (22%) were linked to intact raw beef. Ground beef was responsible for the most illnesses (800, 73%), the two reported deaths, and was the source of the largest outbreak (Canning et al., 2023).

This underscores the ongoing need to ensure the microbiological safety of meat products, which has become a critical concern for both the industry and consumers, as well as public health authorities. Despite a significant reduction in the prevalence of *Salmonella* in meat and poultry products, salmonellosis incidence rates have not declined over the last 15 years in the U.S. This suggests that ground beef is currently regulated only by qualitative *Salmonella* criteria (Strickland et al., 2023).

Vipham et al. (2012) reported the prevalence of *Salmonella* in samples of ground beef and whole muscle retail cuts in the United States was very low, reaching 0.66% in all samples tested. The study also revealed that 0.55% of the ground beef samples contained *Salmonella*. Likewise, the prevalence of *Salmonella* in raw ground beef from FSIS-inspected establishments was 3.36% in fiscal year 2018 and 2.25% in fiscal year 2019 (USDA, 2019).

Despite efforts to control the presence of *Salmonella* in ground beef, conventional detection methods based on culture techniques remain labor-intensive and time-consuming. This, in turn, limits the ability to respond quickly to outbreaks. Consequently, there has been a push to develop and implement more efficient technologies. One notable advancement is the BAX® System, which utilizes PCR-based methods for the rapid and accurate detection of pathogens in food. This automated system focuses on identifying specific genetic markers associated with target organisms, significantly improving the speed and reliability of testing. With a sensitivity and specificity of 98%, the BAX® System is a valuable tool for microbiological monitoring and control in the meat industry (Hygiena, 2021; Wallace et al., 2011).

However, despite advances in microbiological surveillance, there remains a gap in the availability of specific data for regions such as Kansas. Although general data on *Salmonella* prevalence in ground beef in the United States are available, this information tends to be limited to specific geographic areas. Therefore, the objectives of this study were to analyze the prevalence of *Salmonella* in ground beef collected from retail stores in Kansas, determine if there is dependence between prevalence by city, retail store with contamination levels, and analyze the relationship between fat content and the prevalence of *Salmonella* in ground beef.

Materials and Methods

Study Location

The microbiological study and analysis were conducted at Kansas State University, specifically in the Meat Microbiology Research Laboratory, housed within the Department of Animal Science and Industry.

Sample Collection

A total of 278 ground beef samples were collected across the state of Kansas over four months, from February to May 2024. These samples were sourced from 53 retail stores, including supermarkets and other meat markets, in eight cities across Kansas. The collection was performed by the microbiology lab team from Kansas State University, who traveled to each location to acquire the samples, ensuring comprehensive coverage of retail points offering ground beef in each city.

Sample acquisition was based on the availability of ground beef, grinding date, and varying lean meat /fat ratios, including: 70/30%, 80/20%, 81/19%, 85/15%, 86/14%, 90/10%, 93/7%, 95/5%, 96/4%, and 97/3%. Prior to shipment, a laboratory registration form was completed for each sample, with labels indicating store code and sample number, reflecting availability at each store. The samples were shipped to Kansas State University in insulated coolers with frozen gel packs. Upon arrival, samples were processed.

Sample Preparation

Upon receiving the ground beef samples, they were placed on a laboratory bench that had been thoroughly cleaned and disinfected. To prevent external contamination, the packaging of each sample was sterilized with 70% ethanol and allowed to air dry before being carefully opened. Approximately 375 ± 1 grams of ground beef were then transferred directly into 92-ounce Whirl-Pak® bags.

To each sample, 1 liter of BAX® MP medium was added, followed by manual mixing for 30 seconds. After this initial mixing, an additional 0.5 liters of BAX® MP medium were incorporated, and the mixture was combined again for another 30 seconds, resulting in the ground beef primary homogenate (GBPH).

From the GBPH, aliquots were prepared. Thirty milliliters of the homogenized sample were transferred to a sterile 4-ounce sample bag, followed by the addition of 30 milliliters of preheated BAX® MP medium at 42 °C, supplemented with Quant Solution at a concentration of 1 mL/L of BAX® MP medium. The mixture was then gently massaged by hand for 15 to 30 seconds, producing the secondary ground beef homogenate (GBSH). The remaining GBPH was refrigerated at 4 °C until results were obtained. The GBSH was incubated for 6 hours ± 15 minutes at 42 °C ± 1 °C.

Preparation of Detection Lysates

Upon completing the 18 to 24-hour incubation, the GBSH was removed from the incubator for lysate preparation using the BAX® System Real-Time PCR Assay for *Salmonella*. A 5 µL aliquot of GBSH was transferred to Cluster tubes, pre-filled with 200 µL of lysis reagent, and placed in the Automated Thermal Block. The Gram-negative bacteria option was selected, following the protocol, as *Salmonella* is a Gram-negative bacterium. After the cycle was completed, the GBSH aliquots were refrigerated at 2-8 °C, and real-time PCR was subsequently performed.

Preparation of Real-Time PCR

Following the completion of lysis, the detection of Salmonella was conducted using the highly sensitive real-time PCR method with the BAX® Q7 system (Higyena™), which is approved by the Association of Official Analytical Chemists (AOAC) (Hygiena, 2021). This system exhibits sensitivity and specificity rates exceeding 98%. The BAX® Q7 utilizes BAX® MP enrichment media, which supports the recovery of Salmonella during incubation (Hygiena, 2024).

The BAX® Q7 system amplifies specific genes associated with Salmonella, such as the invA gene, which is crucial for identifying pathogenic strains. The detection process employs carefully designed primers that bind to unique DNA sequences of Salmonella, initiating the amplification process (Kadry et al., 2019). Additionally, fluorescent probes are utilized; these probes emit fluorescence upon binding to the amplified DNA sequences, allowing real-time monitoring of the amplification during PCR cycles (avantor, 2024). This combination of methods ensures accurate and rapid detection of Salmonella in various samples.

Statistical Analysis

Chi-square analyses were conducted using the SAS® OnDemand for Academics statistical package to assess whether there was dependence between prevalence and variables such as city, retail store, and fat content, with the significance level set at 95% ($P < 0.05$). Prevalence was calculated using the following formula.

$$Prevalence\ (\%){:}\frac{Total\ of\ positive}{Total\ of\ samples} * 100 \qquad [1]$$

Results and Discussion

Overall Prevalence of *Salmonella* in Ground Beef

Results presented in Table 1 show that, out of 278 ground beef samples collected from retail stores in Kansas, 11 tested positive for *Salmonella*, representing a prevalence of 4%. This rate is significantly higher than the national USDA data for fiscal year 2024, which reported a prevalence of 0.85% across 471 retail samples (USDA, 2024b). This elevated prevalence could be attributed to several factors, as noted by Warmate and Onarinde (2023), including pollution, cross-contamination, inadequate manufacturing practices, poor hygiene standards, temperature abuse, and unsafe food handling practices.

Table 1

General Prevalence of Salmonella in Ground Beef

Bacteria	Total samples	Positives for *Salmonella*	Negatives for *Salmonella*	Prevalence (%)
Salmonella	278	11	267	4.0

Note. Prevalence was calculated by dividing the number of positive samples by the total number of samples and multiplying the result by 100.

A prevalence rate of 4% of Salmonella in meat can pose a risk to consumer health, as even minimal amounts of Salmonella can lead to salmonellosis if the meat is not cooked properly or is mishandled (Laufer et al., 2015). Research by Koohmaraie et al. (2012) indicates that the infectious dose of *Salmonella* can be as low as 15 to 20 cells, a threshold that varies based on factors such as the age and health status of the host and the specific serotype of *Salmonella* involved.

Previous studies have shown variability in *Salmonella* prevalence in ground beef, ranging from 0.55% to 2.25% (USDA, 2019; Vipham et al., 2012). Findings in Kansas, with a 4% prevalence, place it outside this range, highlighting the importance of continued surveillance for *Salmonella* in meat products, as noted by Strickland et al. (2023), who highlight the need for ongoing monitoring, especially in products made from carcass trimmings. Additionally, local factors such as storage and transportation conditions may contribute to elevated contamination levels. Specifically, inadequate temperature control during storage or transportation can facilitate the growth and survival of Salmonella. For instance, fluctuations in refrigeration temperatures may allow the pathogen to proliferate, particularly if the temperatures exceed safe limits. Moreover, improper handling practices during transportation, such as exposure to unsanitary environments or contamination from packaging materials, can introduce or spread *Salmonella* (Broadway et al., 2021).

Further literature highlights even higher prevalence rates; for instance, Bosilevac et al. (2009) reported a 4.2% prevalence in commercially ground beef at the national level, while C. Zhao et al. (2001) found a 2% prevalence in ground beef samples from Washington, DC. These data suggest that *Salmonella* prevalence can vary significantly based on factors like geographical location and meat handling practices. For example, Gebremedhin et al. (2021) reported that Salmonella levels are significantly higher when meat handlers are illiterate, underscoring the importance of education in proper handling practices. Additionally, the study by Canning et al. (2023) supports this notion, noting that 44% of Salmonella outbreaks in the U.S. between 2012 and 2019 were linked to ground beef, largely due to failures in hygienic conditions during meat handling and transportation.

Prevalence of *Salmonella* Determined in Ground Beef by City

Results presented in Table 2 show a significant difference ($p < 0.05$) in the proportion of positive and negative results in cities C2, C5, and C6, reflecting a difference in the prevalence of Salmonella among the cities evaluated. Specifically, C2, C5, and C6 had prevalence rates of 3.3%, 3.4%, and 8.1%, respectively. These rates are substantially higher than the national average reported by the USDA, which indicated a prevalence of 0.85% in retail beef products for fiscal year 2024 (USDA, 2024b).

Table 2

Prevalence of Salmonella Determined in Ground Beef by City

City code	Total samples	Positives for *Salmonella*	Negatives for *Salmonella*	Prevalence (%)	X^2 p-value in each row
C1	21	0	21	0.0	0
C2	30	1	29	3.3	<.0001
C3	11	0	11	0.0	0
C4	10	0	10	0.0	0
C5	89	3	86	3.4	<.0001
C6	86	7	79	8.1	<.0001
C7	27	0	27	0.0	0
C8	4	0	4	0.0	0
X^2 P value					0.4208

Note. A significance level of 0.05 was used for statistical analysis. A p-value less than 0.05 indicates statistically significant differences in each row using the chi-square test.

These findings are concerning, especially when compared to the national baseline prevalence of *Salmonella* in ground meat, reported by Vipham et al. (2012), which was 0.66% across various cities in the U.S. The elevated prevalence observed in Kansas may be attributed to specific regional factors, such as local processing practices, storage conditions, or seasonal influences. According to Jiang et al. (2015), the prevalence of *Salmonella* in ground beef can be affected by geographic region and seasonality, with a tendency for prevalence to rise during the warmer months, leading to higher contamination rates. Similarly, Bosilevac et al. (2009) reported increased *Salmonella* prevalence during the summer, while Vipham et al. (2012) found that rates typically decrease during spring and winter. This seasonal variation was also observed by Akil et al. (2014), who noted a positive correlation between rising temperatures and the incidence of *Salmonella* infections.

However, Williams et al. (2014) reported a well-defined seasonal pattern in the prevalence of *Salmonella* in ground beef, with increased levels observed between July and September, while the lowest rates are recorded from December to June, with April being the month of lowest prevalence. According to this pattern, a low prevalence would be expected during the period in which this study was conducted (February to May). In contrast, the results obtained in cities C2, C5, and C6, where high prevalence rates were observed, differ from those reported by Williams, suggesting that factors beyond seasonality are significantly influencing contamination levels. This highlights the possible influence of local factors, such as processing and storage practices, on the prevalence of *Salmonella* during this period. According to Galán-Relaño et al. (2023), proper hygiene and temperature control during transportation and storage are essential to mitigate the proliferation of *Salmonella*. Ehuwa et al. (2021) and Da Silva et al. (2022), emphasize that poor hygiene and ineffective temperature control during meat processing can allow *Salmonella* to persist and even proliferate, significantly increasing the risk of outbreaks. Additionally, deficiencies in sanitation protocols and inadequate handling practices in processing facilities contribute considerably to the prevalence of pathogens, underscoring the importance of implementing strict controls throughout the supply chain (Anas et al., 2019).

Smaller facilities may also face challenges in maintaining hygiene standards, which can lead to higher prevalence rates, as noted by Wang et al. (2014). This is consistent with findings by Williams et al. (2020), who also suggested that regional disparities in contamination levels often correlate with local handling and processing practices, underscoring the impact of facility size and hygiene protocols.

Meanwhile, cities C1, C3, C4, C7, and C8 did not report any *Salmonella* positive samples, which aligns with USDA data for the second quarter of fiscal year 2024. After analyzing 123 samples, no positive cases were found, resulting in a reported prevalence of 0.00% for *Salmonella* in retail ground beef (USDA, 2024b). The absence of contamination in these cities may be attributed to the effective implementation of meat handling and processing practices, creating conditions less conducive to pathogen proliferation. This is consistent with Wheeler et al. (2014), who found that effective quality control and food safety protocols can greatly reduce pathogen contamination in meat products.

Although the overall p-value from the chi-square analysis was 0.4208, indicating no statistically significant difference in *Salmonella* prevalence among all the cities evaluated at a 0.05 significance level.

Prevalence of *Salmonella* Determined in Ground Beef per Retailer Code

Analysis of Table 3 reveals notable variations in the prevalence of *Salmonella* among different retail stores. While most stores showed a prevalence of 0%, certain stores such as T13, T18, T28, T33, and T34 displayed prevalence rates exceeding 6%, with statistically significant differences ($p < 0.05$). This suggests that specific handling and storage conditions in these stores may have contributed to the elevated prevalence of *Salmonella*.

Upadhyaya et al. (2012) highlighted that factors such as the store's hygienic conditions, the type of store, the number of individuals handling the meat, and the number of knives used are significantly associated with *Salmonella* contamination in retail environments. Furthermore, *Salmonella* contamination tends to be higher in supermarkets compared to open markets (Xu et al., 2020), which may explain the elevated prevalence observed in these particular stores. It is important to emphasize that hygiene and storage temperature are critical in controlling the presence of pathogens in meat products. Previous studies also confirm that inadequate sanitation practices, both at the farm level and by retailers, can increase the risk of microbial cross-contamination at points of sale (Huoy et al., 2024).

Specifically, stores T13, T18, T28, T33, and T34 exhibited significant prevalence rates, with statistically significant differences ($p < 0.05$). These variations in *Salmonella* prevalence could potentially be related to less stringent food handling practices and possible failures in maintaining proper cold chain control during transportation and storage, as suggested by research in similar contexts. Yang and Cai (2013) also highlight that inadequate temperature control throughout cold chain logistics significantly increases the risk of microbial contamination in food products. Research by Kebede and Getu (2023) demonstrated that stores with poor temperature control and inadequate hygiene protocols tend to have a higher prevalence of *Salmonella* in ground meat. Therefore, it is likely that these specific stores present deficiencies in meat handling that promote contamination. Similarly, Gebeyehu and Tsegaye (2022) and Azanaw et al. (2019) mention that insufficient staff training in hygiene practices and meat handling, along with inadequate biosecurity measures and surface cleaning, significantly increase the risk of contamination by pathogens like Salmonella. This underscores the need to implement staff training programs and conduct more stringent audits to reduce the prevalence of pathogens in retail environments.

Overall, the prevalence of *Salmonella* in ground beef samples was not significant ($p > 0.05$) in most stores, while this may suggest that some retailers are implementing effective control measures to prevent contamination. As Marshall et al. (2018) noted, that rigorous compliance with food safety regulations can markedly reduce pathogen prevalence, such as *Salmonella*, in meat products. Furthermore, the Centers for Disease Control and Prevention (2006) emphasizes that proper handling practices in the food industry, along with increased education for both food handlers and consumers, play a crucial role in reducing the risks of foodborne salmonellosis.

However, those stores with elevated *Salmonella* prevalence present a substantial risk to public health, as contaminated ground beef remains a leading cause of foodborne illness (USDA, 2024a).

Table 3

Prevalence of Salmonella Determined in Ground Beef per Retailer Code

Store code	Total samples	Positives for *Salmonella*	Negatives for *Salmonella*	Prevalence (%)	X^2 p-value in each row	Store code	Total samples	Positives for *Salmonella*	Negatives for *Salmonella*	Prevalence (%)	X^2 p-value in each row
T1	14	0	14	0.0	0	T28	10	1	9	10.0	0.0114
T2	2	0	2	0.0	0	T29	6	0	6	0.0	0
T3	5	0	5	0.0	0	T30	5	0	5	0.0	0
T4	1	0	1	0.0	0	T31	6	1	5	16.7	0.1025
T5	12	0	12	0.0	0	T32	6	1	5	16.7	0.1025
T6	4	0	4	0.0	0	T33	16	1	15	6.3	0.0005
T7	3	1	2	33.3	0.5637	T34	15	2	13	13.3	0.0045
T8	10	0	10	0.0	0	T35	3	0	3	0.0	0
T9	11	0	11	0.0	0	T36	2	0	2	0.0	0
T10	10	0	10	0.0	0	T37	4	0	4	0.0	0
T11	3	0	3	0.0	0	T38	3	0	3	0.0	0
T12	8	0	8	0.0	0	T39	2	0	2	0.0	0
T13	10	1	9	10.0	0.0114	T40	2	0	2	0.0	0
T14	1	0	1	0.0	0	T41	2	0	2	0.0	0
T15	6	1	5	16.7	0.1025	T42	1	0	1	0.0	0
T16	10	0	10	0.0	0	T43	1	0	1	0.0	0
T17	7	0	7	0.0	0	T44	2	0	2	0.0	0
T18	11	1	10	9.1	0.0067	T45	1	0	1	0.0	0
T19	8	0	8	0.0	0	T46	2	0	2	0.0	0
T20	5	0	5	0.0	0	T47	2	0	2	0.0	0
T21	6	0	6	0.0	0	T48	1	0	1	0.0	0
T22	7	0	7	0.0	0	T49	2	0	2	0.0	0
T23	7	0	7	0.0	0	T50	1	0	1	0.0	0
T24	4	0	4	0.0	0	T51	1	0	1	0.0	0
T25	2	1	1	50.0	1	T52	1	0	1	0.0	0
T26	10	0	10	0.0	0	T53	1	0	1	0.0	0

Store code	Total samples	Positives for *Salmonella*	Negatives for *Salmonella*	Prevalence (%)	X^2 p-value in each row	Store code	Total samples	Positives for *Salmonella*	Negatives for *Salmonella*	Prevalence (%)	X^2 p-value in each row
T27	3	0	3	0.0	-	X P value					0.8890

Note. A significance level of 0.05 was used for statistical analysis. A p-value less than 0.05 indicates statistically significant differences in each row using the chi-square test; T7 belongs to category C2; T13, T15, and T18 belong to category C5; T25, T28, T31, T32, T33, and T34 belong to category C6.

Prevalence of *Salmonella* Determined in Ground Beef by Fat Percentage

Samples with fat contents of 7%, 10%, 15%, and 20% showed statistically significant prevalence rates ($p < 0.05$), with the 15% fat samples exhibiting the highest prevalence levels, as detailed in Table 4. These findings are consistent with reports from the CDC (2024), which indicated that 64% of patients affected by a Salmonella outbreak recalled consuming ground beef containing 85% lean meat and 15% fat. This suggests that samples with intermediate fat levels, classified as such by the USDA (2024a) due to their fat content ranging from 12% to 22%, like those evaluated in this study, could pose a higher risk to consumer health, given the observed relationship between fat content and pathogen prevalence. These findings are consistent with reports from the CDC (2023), which linked a *Salmonella* outbreak to the consumption of ground beef, especially in products with higher fat content (20%).

Table 4

Prevalence of Salmonella Determined in Ground Beef by Fat Percentage.

Fat (%)	Total samples	Positives for *Salmonella*	Negatives for *Salmonella*	Prevalence (%)	X^2 p-value in each row
3	1	0	1	0.0	-
4	1	0	1	0.0	-
5	4	0	4	0.0	-
7	69	2	67	2.9	<.0001
10	44	2	42	4.5	<.0001
14	1	0	1	0.0	-
15	50	5	45	10.0	<.0001
19	3	0	3	0.0	-
20	85	2	83	2.4	<.0001
30	2	0	2	0.0	-
X^2 P value					0.7705

Note. A significance level of 0.05 was used for statistical analysis. A p-value less than 0.05 indicates statistically significant differences in each row using the chi-square test.

Foods with low water activity (aw), including those containing fat, have frequently been implicated in outbreaks of *Salmonella spp*. Trimble et al. (2020), suggesting that fat content in ground beef may be linked to its ability to promote pathogen survival. Juneja and Eblen (2000) also noted that fat content can influence water activity, affecting moisture retention and, consequently, the survival of pathogens such as *Salmonella* in meat products. However, Akritidou et al. (2023) observed that fat offers lower protective capacity, and that low-fat products may be associated with the development of stress resistance in pathogens.

Nevertheless, other studies have found no direct correlation between fat content and *Salmonella* presence. For instance, a recent study analyzing ground beef from retail stores, with samples ranging from 96% lean and 4% fat to 73% lean and 27% fat, found that fat percentage did not significantly differ between *Salmonella* positive and negative samples (P = 0.82) (Vipham et al., 2012).

Similarly, T. Zhao et al. (2002) noted that although some samples with 7%, 10%, and 27% fat contained *Salmonella*, no direct correlation was identified between fat percentage and the prevalence of the pathogen in ground beef samples collected from cities like New York, San Francisco, and Chicago.

The presence of Salmonella in ground beef can be influenced by several factors, including lymph nodes, which have been identified as a potential source of contamination. According to Tilton et al. (2024), lymph nodes, which are surrounded by fat, can be accidentally incorporated into ground beef during processing, thereby increasing the risk of contamination. Similarly, Koohmaraie et al. (2012) pointed out that the complete removal of lymph nodes during carcass processing is practically impossible, which increases the likelihood of their inclusion in ground beef. Gragg et al. (2013) highlighted that lymph nodes can be a significant source of Salmonella, especially in conventionally raised feedlot cattle. Wottlin et al. (2022) also found a 32% prevalence of Salmonella in the lymph nodes of this type of cattle. Likewise, Levent et al. (2019) reported that the prevalence of Salmonella in lymph nodes could rise to as much as 75.4% in cattle fed before slaughter, further emphasizing the importance of handling practices in the prevalence of this pathogen.

Furthermore, T. Zhao et al. (2002)emphasized that other contamination sources, including production and distribution processes, highlight the need for improved handling and processing practices throughout the supply chain, regardless of the meat's fat content, as *Salmonella* contamination risks are not solely limited to this factor.

Although products with higher fat content may be associated with greater moisture retention, which could potentially facilitate the survival of Salmonella, the results of this study do not show a dependence between fat content and the prevalence of Salmonella in ground beef ($P > 0.05$). Furthermore, the observed correlation value was 0.0721; therefore, there is no direct relationship between fat content and the presence of *Salmonella* in the samples.

Conclusions

The study revealed that prevalence of *Salmonella* in ground beef in Kansas (4%) is higher than the national average (0.85%) reported by USDA for FY2024.

No significant differences were determined in the prevalence of *Salmonella* among the cities or retail stores. However, some cities and stores showed higher prevalence rates compared to the national average.

No significant differences were determined in the prevalence of *Salmonella* in relation to the fat content in ground beef.

Recommendations

Conduct longitudinal studies over time to identify seasonal patterns of contamination.

Conduct a serotype analysis to identify which Salmonella serotypes are most common in ground beef in Kansas.

Increase the sample size, with particular focus on the cities and stores that reported the highest prevalence in this study.

Standardize the sample size for each variable to enhance the representativeness, homogeneity, and statistical comparability of the dataset.

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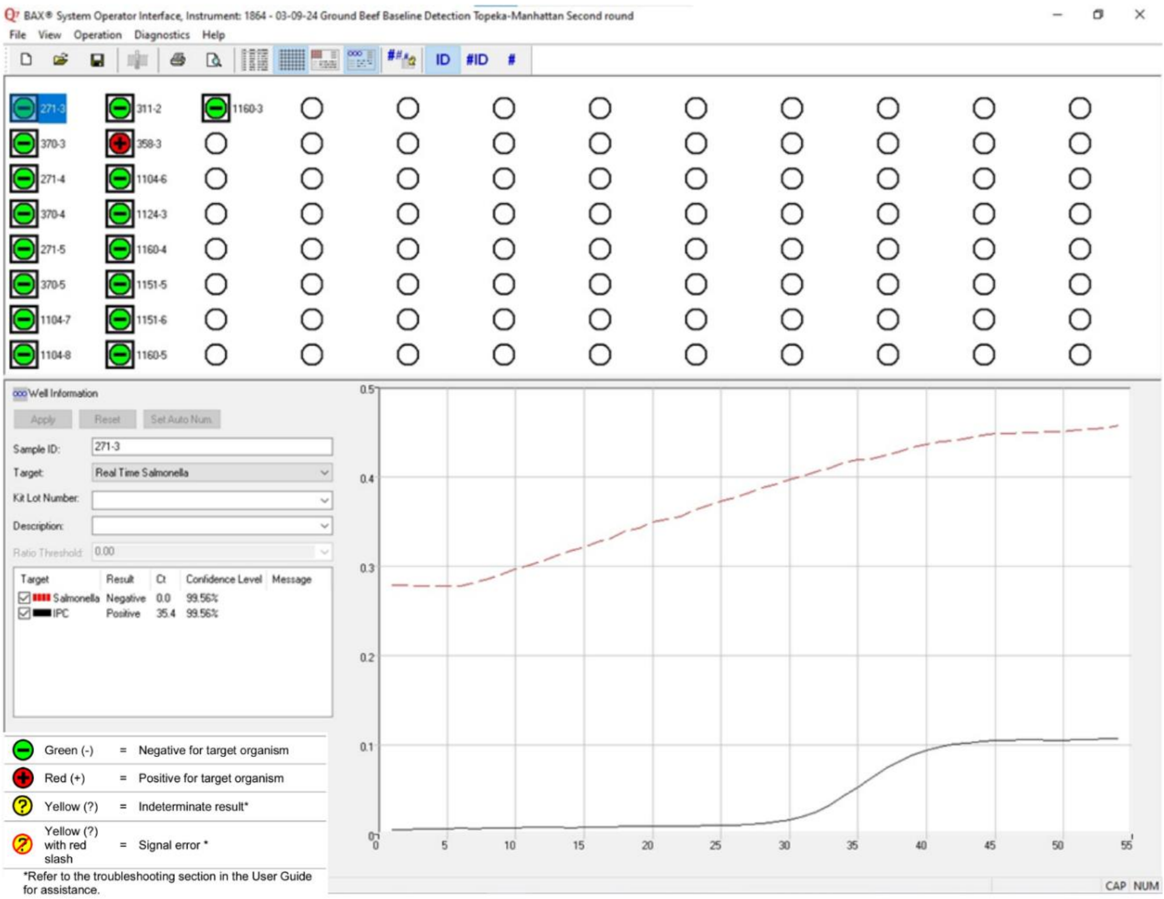
Appendices

Appendix A

BAX® Q7 System Equipment

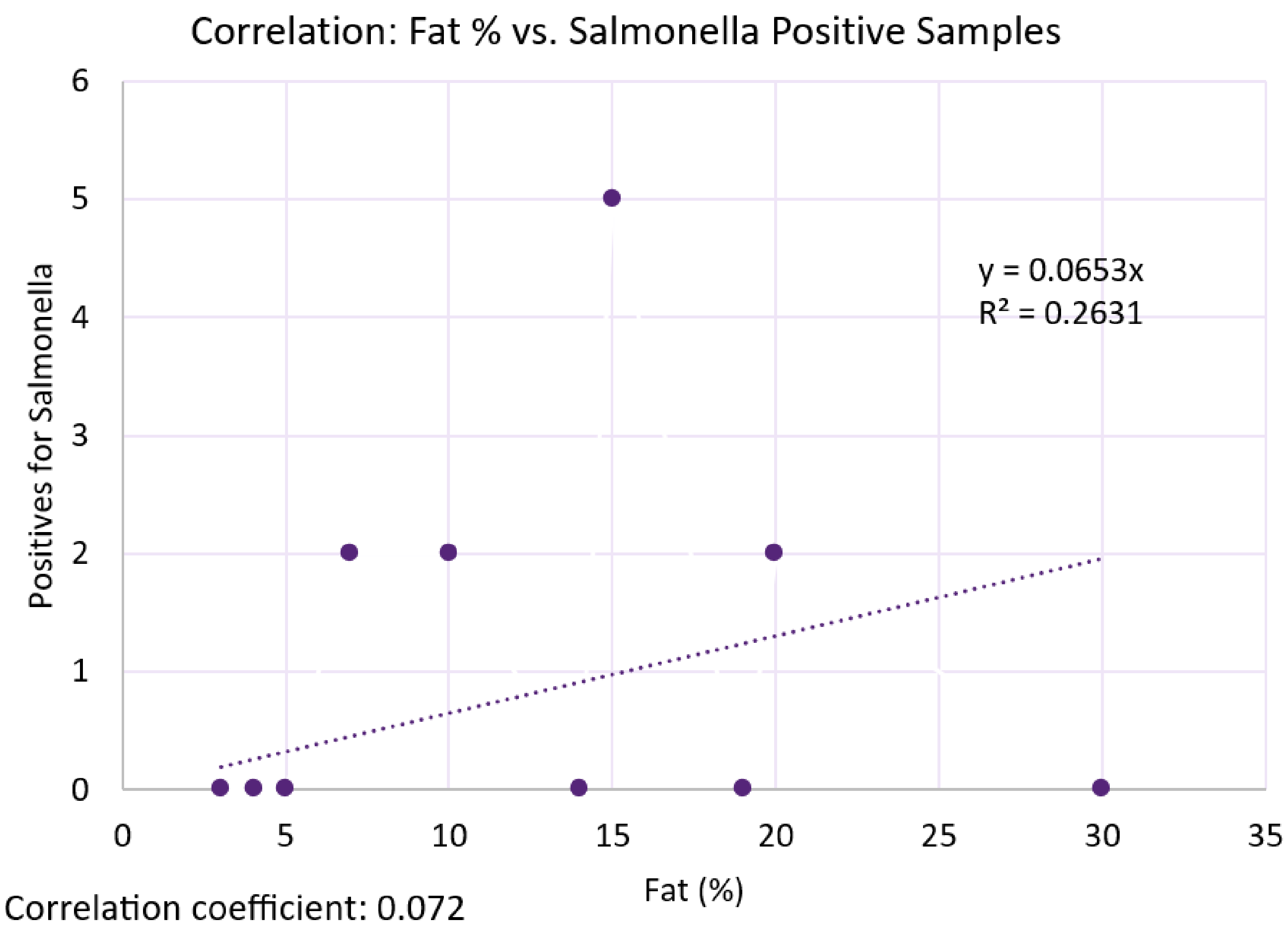
Appendix B

Salmonella Detection Results



Appendix C

Correlation: Fat % vs. Salmonella Positive Samples



Appendix D

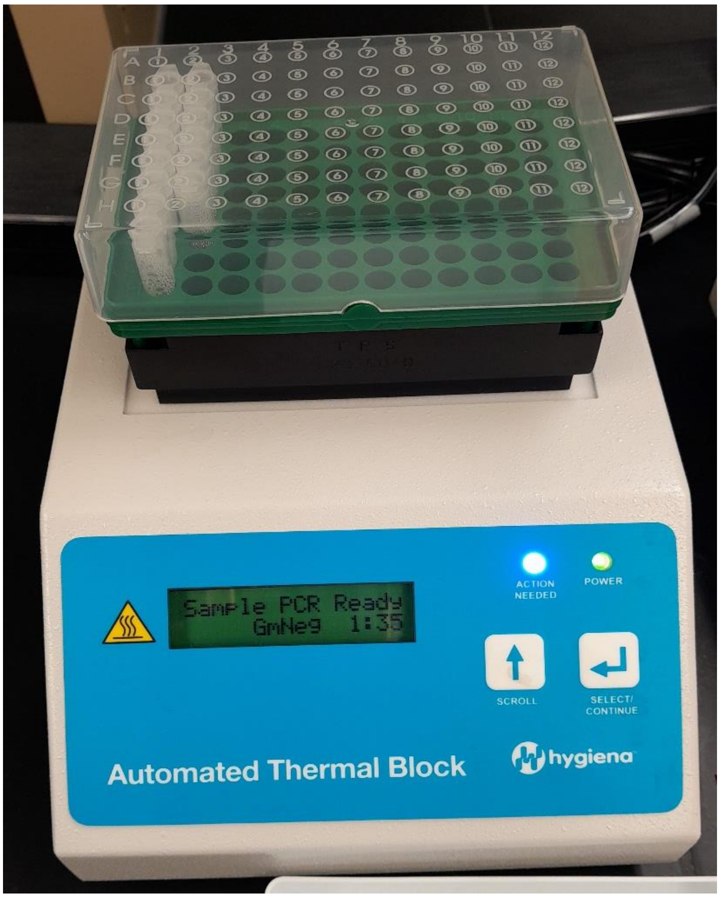
BAX® System MP Media

Appendix E

Ground Beef Samples

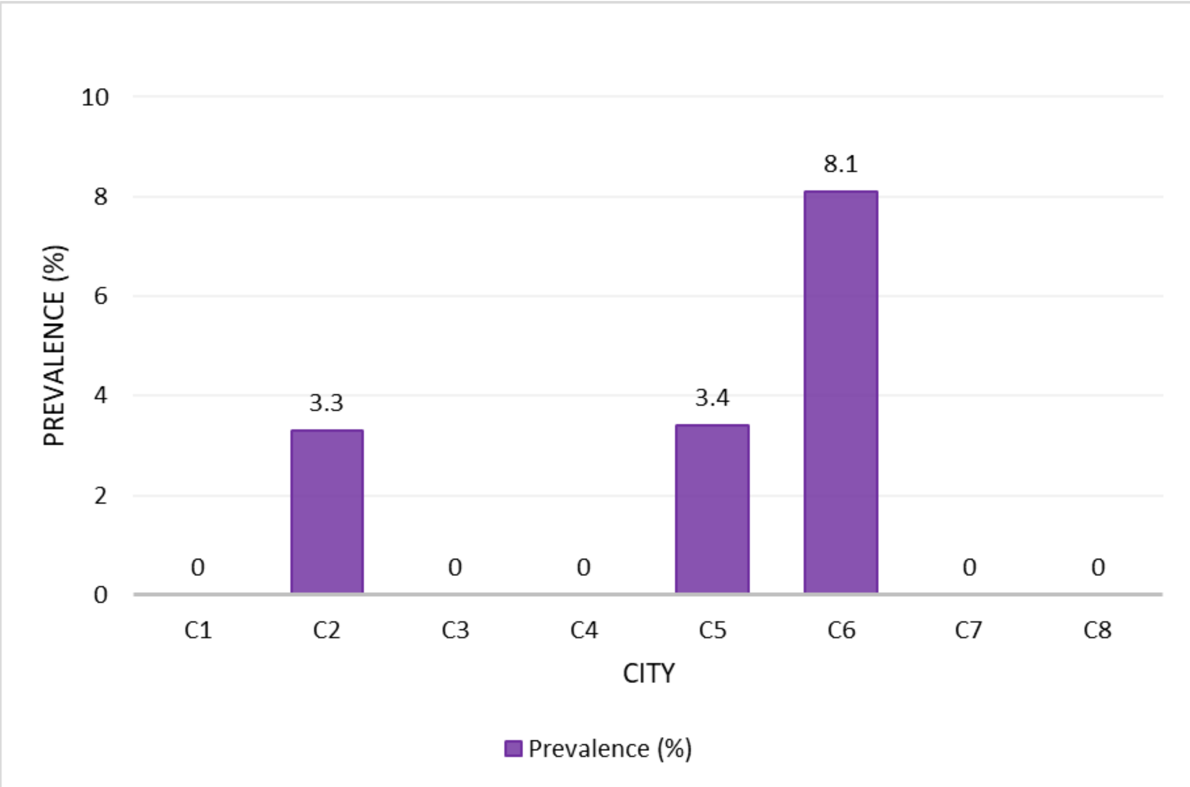
Appendix F

Automated Thermal Block



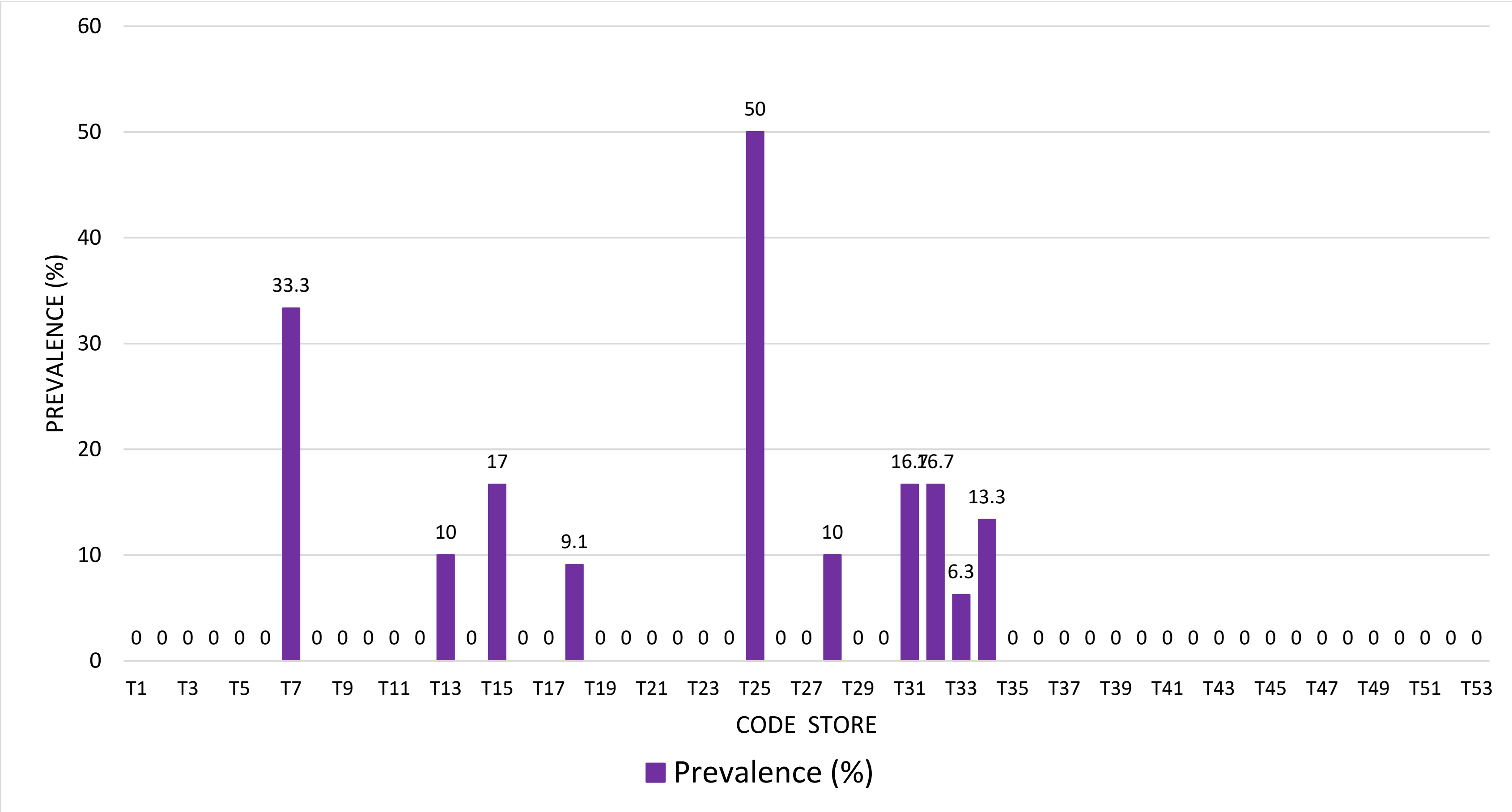
Appendix G

Prevalence of Salmonella Determined in Ground Beef by City



Appendix H

Prevalence of Salmonella Determined in Ground Beef per Retailer Code



Appendix I

Prevalence of Salmonella Determined in Ground Beef by Fat Percentage